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## Rationalization of water treatment as a top priority goal of sustainable development of residential areas and improvement of environmental quality

To cite this article: A Rumyantseva *et al* 2018 *IOP Conf. Ser.: Earth Environ. Sci.* **177** 012031

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# Rationalization of water treatment as a top priority goal of sustainable development of residential areas and improvement of environmental quality

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**Abstract.** The problem of searching for resource-saving and cost-effective technologies for cleaning rinsing water within the filter structures of waterworks remains relevant for many years. Most of contaminated wastewater of Sverdlovsk Region comes to the surface water bodies from Municipal Unitary Enterprise ‘Vodokanal’. The solution of engineering tasks aimed at the environmental situation improvement in urban areas and water bodies protection from pollution subsequently requires continuous improvement of wastewater treatment methods. The paper examines the construction project of rinsing waters treatment unit of the filter station of Municipal Unitary Enterprise ‘Vodokanal’ with the formation of dehydrated sludge and provides the calculations of technical and economic parameters of the project. The project implementation is expected to result in a decrease of the man-caused environmental impact by eliminating the rinsing waters discharge, as well as by reducing the amount of water taken from the surface source into the technological process of potable water treatment.

## 1. Introduction

In the modern world, ecology is one of the basic components of the concept of favorable human habitat, along with its social and economic aspects. In the context of a global climate balance change, which has a significant impact on the redistribution of water resources, the public's attention is substantially focused on the problem of quality and usage of water resources.

According to the UN, potable water will play a decisive role on the Agenda of the Third Millennium. In 2000 the fresh water shortage within our planet, including agricultural and industrial needs, was estimated at 230 billion cu. m per year. By 2025 this number is expected to increase up to 1.3–2.0 trillion cu. m per year.

In terms of total freshwater resource amount, Russia has a leading position among the European countries. Russia is said to have more than 20 % of the world's freshwater resources in reserves (excluding glaciers and groundwater). Among the six countries with the largest river flow (Brazil, Russia, Canada, the United States of America, China, India), Russia is the second largest in the world after Brazil, and the third one in terms of water availability per capita (after Brazil and Canada) [1].

Environmental and water management safety is a guarantee not only for the industrial complex development of the country, but also for the development of the economy and for the population well-



being. Absence of necessary and sufficient amount of good quality potable watery is already a serious problem nowadays.

## 2. Facts and figures of water management and wastewater disposal in the Russian Federation

Water management in Russia is carried out in an overwhelming degree due to the fresh water intake. In 2010, fresh water intake from water bodies was 72.7 billion cu. m; in 2011 – 68.7; in 2012 – 66.3; in 2013 – 65.1; in 2014 – 64.8; in 2015 – 62.2 and in 2016 – 63.0 billion cu. m.

Thus, there is a sustainable trend for the decrease of the indicator mentioned above, except for the last year. In 2015, the volume of contaminated wastewater discharged into the country's water bodies reduced to 14.4 billion cu. m, in other words it was 2.4 % less than in 2014. In 2016, this figure increased up to 14.7 billion cu. m, in other words it became 2.1 % more than a year earlier.

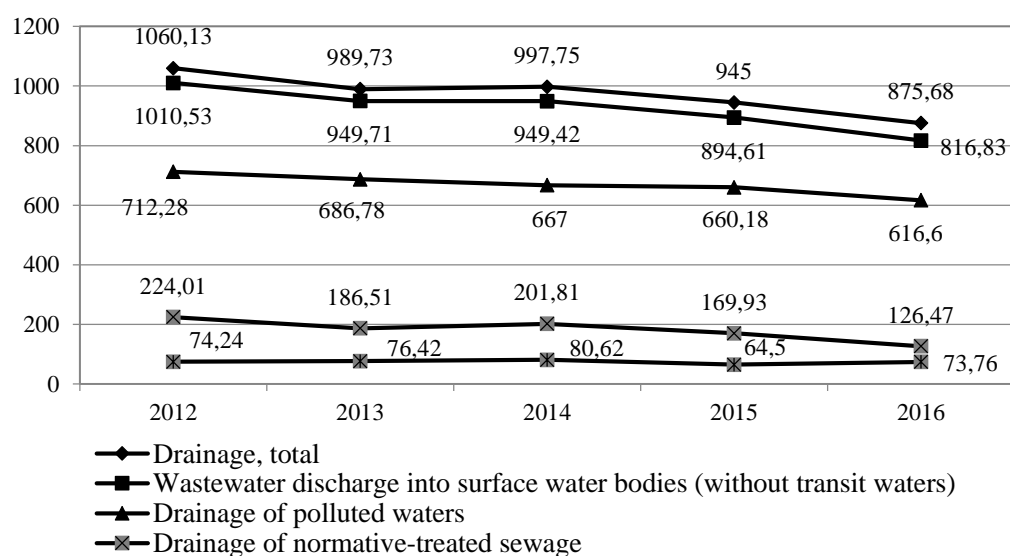
The share of polluted wastewater in the total amount of wastewater discharge in water bodies in 2010, 2014 and 2015 remained generally stable and its value is about one third. This, to some extent, indicates that the overall dynamics of the water usage and sewerage significantly influenced the change in the wastewater discharge under consideration. At the same time, it should be noted that, despite appreciable positive trends in the absolute change of the wastewater discharge, its relative share in the total volume of wastewater disposal in water sources has remained unchanged in recent years (its value is about one third).

According to Roshydromet (Russian meteorological service), in 2016, there were 2,990 cases of high pollution (HP) and extremely high pollution (EHP) registered within the territory of the Russian Federation. Extremely high levels of surface water pollution occurred in 638 cases at 136 water bodies, which is 6 % more than in 2015 (598 cases at 144 water bodies). High levels of pollution were observed in 2352 cases at 321 water bodies (in 2015 – 2423 cases at 331 water bodies). Over the past five years, the total amount of HP and EHP of surface waters remains approximately at the same level.

Over the past ten years, if compared with other subjects of the Russian Federation, Sverdlovsk region has the largest number of cases of HP and EHP [1].

## 3. Facts and figures of water management and wastewater disposal in Sverdlovsk region

The quality of the surface waters is largely formed under the influence of economic activity, primarily under the influence of industrial and domestic wastewater discharges. While the share of discharged polluted wastewater in the Russian Federation in 2016 is 34.2 % of the total volume of wastewater discharge [1], the same value in Sverdlovsk region is 75 % [2].



**Figure 1.** Dynamics of wastewater disposal in Sverdlovsk region (million cu. m)

The dynamics of wastewater disposal in Sverdlovsk region is shown on Fig. 1.

The greatest amount of contaminated wastewater enters the surface water sources of the region from a number of enterprises working in the spheres of:

communal services – 55 percent;

processing industries – 30 percent;

minerals extraction – 9 percent.

The list of enterprises which are the main sources of pollution of surface water bodies in Sverdlovsk region in 2015–2016 is given in table 1.

**Table 1.** List of enterprises which are among the main sources of pollution of surface water bodies in Sverdlovsk region in 2015–2016

No.	Name of the Enterprise	Wastewater discharged, total (mln cu. m)		Contained wastewater discharged (mln cu. m)	
		2015	2016	2015д	2016
1.	Municipal Unitary Enterprise ‘Vodokanal’, Municipal Settlement ‘Yekaterinburg City’	144.90	135.24	144.90	135.24
2.	OOO ‘Vodokanal-NT’, Nizhny Tagil, Gornouralsky Urban District	44.39	41.71	44.39	41.71
3.	Joint-stock company ‘EVRAZ Nizhny Tagil Metallurgical Complex’, Nizhny Tagil, Gornouralsky Urban District	29.20	33.43	29.20	33.43
4.	PAO ‘Uralchimplast’, Nizhny Tagil	31.97	28.95	31.97	28.95
5.	Joint-stock company ‘Siberian-Urals Aluminium Company’, Krasnoturinsk Urban District, Kamensk- Uralsky	25.66	27.40	25.66	27.40
6.	Pervouralsk Production Municipal Unitary Enterprise ‘Vodokanal’, Pervouralsk Urban District	24.15	20.77	24.11	20.73
7.	PAO ‘VSMPO-AVISMA Corporation’, Verkhnyaya Salda Urban District	20.25	20.22	20.21	20.18
8.	Municipal Unitary Enterprise ‘Vodokanal’, Novouralsk Urban District	19.88	16.66	19.88	16.66
9.	OAO ‘Vysologorsky Ore Mining and Processing Industrial Complex’, Urban District of Kushva, Nizhny Tagil	15.18	16.41	15.11	16.41
10.	Joint-stock company ‘Vodokanal KU’, Kamensk- Uralsky	16.75	16.03	16.75	16.03

As it can be seen from table 1, contaminated sewage of urban utilities is the main source of pollution of surface water bodies of regional cities. The largest volume of contaminated wastewater after biological treatment comes to surface water bodies from Municipal Unitary Enterprise ‘Vodokanal’ which has 22 % of the total discharge of contaminated sewage in Sverdlovsk region [2].

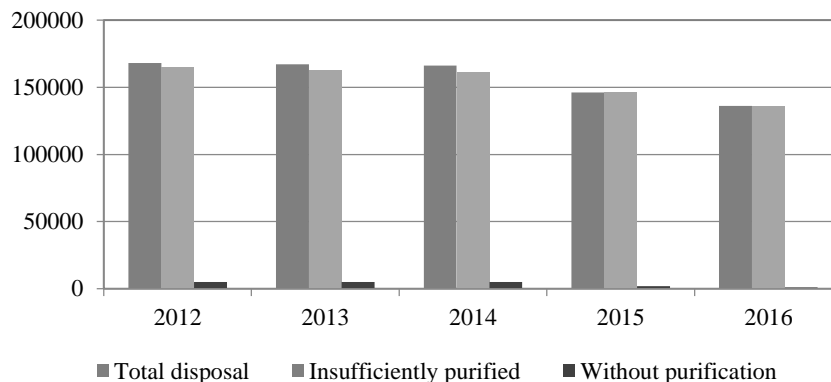
The data provided in accordance with the state statistical report of 2TP Vodkhoz for consecutive five years dynamics of water disposal by Municipal Unitary Enterprise ‘Vodokanal’ in Yekaterinburg is shown on Fig. 2.

#### 4. Importance of modernization and improvement of water treatment facilities

Transition of Russia towards the technological standardization makes modernization and improvement of water treatment facilities important. Technological standardization process is regulated by the information and technical reference book ITRB 10-2015 ‘Waste Water Treatment Using Sewerage for Settlement and Urban Districts’ [3].

Along with the changes in the system of wastewater disposal from municipal facilities and according to the Federal Law No. 7-FZ, newly adopted Federal Law No. 225-FZ has completely changed the technological regulation system of sewerage for settlements (VSSS) [4], which was

previously reflected in Chapter 5 of Federal Law No. 416-FZ ‘About water supply and Sewerage’ [5]. Starting from 2019, the technological regulation system of wastewater treatment facilities will become completely different.



**Figure 2.** Dynamics of wastewater disposal of Municipal Unitary Enterprise ‘Vodokanal’

The practical implementation of the system of technological regulation was initiated by the adoption of the Federal Law of 21.07.2014 No. 219-FZ [6]. Starting from 2019 this document will radically change the existing principle of standardization of the impact of production and economic activities on the environment, including wastewater discharge into surface water bodies: it provides the transition from water quality standards established for water objects for fishery usage towards regulation established on the basis of the best available technologies. The law considers the essential features of the municipal sewerage industry. It is very important that the law discloses the basic provisions of ITBR 10-2015 on linking the technological indicators of BAT with the categories of water bodies and the size of municipal wastewater treatment facilities. In addition, the law will seriously reduce the fees charged to the water companies for discharging pollutants [7, 8].

Thus, in order to improve the quality of discharged wastewater and to reduce its impact on water sources and the volume of discharges, it is necessary to build new wastewater treatment facilities or reconstruct and expand existing ones, build local treatment facilities, post-treatment units, and start using recycling and water reuse systems.

Despite the actual quality of surface water sources, clean potable water provision for the population is accompanied by the formation of contaminated rinsing waters and waste sediments, which also make a significant contribution to the pollution of water bodies and represent a problem that needs to be addressed. The amount of the rinsing waters is 7–10 % of the average amount of daily water consumption.

The sediment formed in the process of water purification, as a rule, is less dangerous for the environment and a human himself than, for example, the wastewater sediment is. At the same time, water sediment (especially formed during the purification of high values of water color and low-turbid waters) has higher values of the resistivity index of filtration and requires high costs for thickening and dehydration. Placement of water sediment in accumulation reservoirs or on dehydration sites leads to the expropriation of significant land areas that have been withdrawn from economic use for a long time, which is especially important for large cities. In addition, the hydroxide precipitate, in its original form, often poses a certain danger to the environment and the man, since the substances contained in it can, under certain conditions, be included in geochemical and biogeochemical cycles [9, 10].

The problem of water sediment is most often solved by its discharge into the lower lands, water bodies and streams, by placing it on silt areas (lagoons) with drying and subsequent export to dumps. Until recently, in many countries of the world, including Russia, the water sediment (with a single use of the coagulant) was often discharged in the form of sludge pulp into water bodies and streams, which

resulted in the supply of significant amounts of sedimentary material contaminated with products of hydrolysis of coagulants and various impurities contained in reagents and isolated from the source water. Negative ecological phenomena are also observed when placing water sediments at dehydration sites or in oxidation ponds.

The problem of finding resource-saving and cost-effective technologies for cleaning rinsing waters on the filter structures of waterworks is urgent.

This task is strategically important for the sustainable development of the urban environment and improving the quality of life of the population of the city of Yekaterinburg.

### **5. Feasibility study for the construction of a rinsing waters treatment and sludge dewatering unit at the main waterworks of MUE 'Vodokanal', Yekaterinburg**

To solve this problem at the main waterworks of MUE 'Vodokanal', it is necessary to build a rinsing waters treatment and sludge dewatering unit. This workshop will allow not only to exclude the discharge of polluted rinsing waters into the environment, but also to substantially reduce the required intake of fresh water due to the re-use of rinsing waters, the main pollutant of which is suspended solids.

The aim of the project is to process the rinsing waters of the filter station of the Municipal Unitary Enterprise 'Vodokanal' along with the production of a dehydrated sediment in order to reduce the man-made influence on environment by eliminating the rinsing waters discharge, as well as by reducing the amount of water intake from the surface sources into the technological process of water purification.

The urgency of the project is explained by the high level of pollution of the reserve water source with its own production waste, a high payment for the negative impact on the environment, decrease in the quality of life and in the urban development.

Nowadays, various modern sludge dewatering technologies are used. Advantages of mechanical sludge dewatering include high productivity, reduction of the required area of the site due to elimination of waste areas, elimination of unpleasant odors, reduction of number of maintenance personnel, absence of climate factors influence on the dehydration process.

In the process of investigation, the authors considered three methods of mechanical sludge dewatering, among which are a chamber filter press, a band filter press and a decanter [9, 10].

A strip press filter will be used in this project due to the combination of low energy consumption, acceptable dehydration rates and low initial investment.

Realization of the investment program of the enterprise for 2014–2025 "Development of Water Supply and Sewerage Infrastructure" [11] is expected to result in the performance increase of the station from 120 to 300 thousand cu. m per day. This will lead to an increase in the total amount of discharged rinsing waters, and, as a consequence, to the increase in the amount of sediment.

Laboratory tests conducted at the plant in 2016 showed that a significant rate of water contamination was influenced by the dry residue and suspended solids. The average monthly suspended solids content in the discharged water is 67.3 g / cu. m, which is about 30 %. Regularly a filter station discharges about 353.73 tons of suspended solids per year. As a result of station modernization and reaching full working capacity, this figure will reach 880 tons per year.

Dewatered sediment can be used for disturbed lands remediation. The evaluation of the water treatment sludge in terms of its suitability for remediation was carried out in the Analytical Laboratory of the Ural State Mining University in accordance with the appropriate standards for remediation. The evaluation revealed that three main indicators (pH, dry residue and the amount of toxic salts in the water extract) show that the water treatment residue belongs to the potentially fertile group.

Sediments represent poor soluble multicomponent mixtures, the priority components of which are aluminum, iron, calcium, silicon, manganese. The solubility of sediments is negligible. Sediments are not a radiological hazard; they do not have any ecotoxicological properties. Based on this, they are classified as non-toxic, environmentally safe waste [9, 10 and 12]. The sediment corresponds to the requirements for soils of sanitary protection zones (land allocation for transmission lines).



Calculation of fees for negative impact on surface water bodies by the rinsing waters of the filter station was carried out in accordance with the tariffs set by the Russian Federation Government Decree No. 913 dated of September 13, 2016 [13]. In carrying out all the proposed measures, the absence of payment for negative impact can be considered as an additional economic effect. According to the conditions of the previous negative impact, its value is estimated for more than 800 million rubles per year for the maximum performance of the filter station.

The results of laboratory studies of the contamination of rinsing waters after the removal of suspended solids unequivocally confirm that this water is not advisable to be discharged, because it is most suitable for potable water. The biological oxygen demand (BOD<sub>20</sub>) approximately coincides with the BOD of the water source. According to inorganic components, the same statement applies to the rigidity of water, to the content of dry matter, chlorides, sulfates, calcium and magnesium. Water contains an average of 1–2 g / cu. m of active chlorine, which corresponds to the level of microbiological indicators. Thus, up to 84 % of the generated water is returned to the water treatment process and can be used for re-treatment and further transportation to the consumer (Table 2).

**Table 2.** The amount of washing waters formation and process water usage

Capacity of filter station, thousands of cu. m per day	Amount of rinsing waters, thousands cu. m per day	Amount of water returned to the technological process, thousands cu. m per day
120	14.4	12.1
150	18.0	15.1
300	36.0	30.2

For the implementation of the project, it is necessary to purchase vehicles (dumper), equipment for the site (flotator, compressor, belt press filter, sludge pump, flotation water pump, metering pump) and to build the facility itself. The total amount of investments is estimated at 2,221,097 rubles. The sources of this project is investment program (investment component in the tariff for the potable water) and budgetary appropriations (finances of budget funds of various levels). Project implementation period is 12 years.

The project includes the calculations on the operating costs for sludge dewatering and rinsing waters treatment in accordance with the calculations on the increase in the performance of filter station; the cost of water treatment is also determined. The profit of the enterprise, which results from the use and recycling of rinsing waters is shown in Table 3.

**Table 3.** Profit from rinsing waters recycling

Period	Cubic capacity of water recycling, thous. of cu. m per year	Cost of the drinking water		Cost of the drinking water		Profit, thous. of RUB per year
		Rate, RUB.	thous. of RUB per year	Rate, RUB.	thous. of RUB per year	
2020	4362.48		37517.32		150941.81	113424.48
2021–2023	5453.10	8.60	46896.66	34.60	188677.26	141780.60
2024–2029	10906.20		93793.32		377354.52	283561.20

**Table 4.** The main indicators of economic efficiency of the project

No.	Indicator Description	Unit of measurement	Indicator values
1	Net profit	thous. of RUB	6 771 597.22
2	Net present value	thous. of RUB	729 037. 82
3	Pay-back period	years	4.84
4	Return on investment index	–	3.05
5	Return on discounted investment index	–	1.33
6	Internal rate of return	%	21.38

The main indicators of the economic efficiency of the project calculated with the 15 % discount rate are given in Table 4.

Analyzing the obtained indicators of the economic efficiency of the project, it can be concluded that the project for the organization of the sludge dewatering site at the municipal unitary enterprise 'Vodokanal' is cost-efficient and advisable for implementation.

## 6. Conclusion

The problem of safe sludge deposition and the use of rinsing waters purification technologies on filter stations is extremely relevant for Russia, where surface water is the main source of centralized water supply. In this regard, the implementation of the proposed project is important and cost-effective. The main ecological results of the project are:

1. exclusion of dumping of contaminated rinsing waters from MUE 'Vodokanal' facilities and its reuse in the technological process;
2. prevention of harm caused to water resources and soils;
3. utilization of the dehydrated sediment and obtaining of the final product;
4. reduction of the amount of fresh water intake from the surface water source.

Final decision on the choice of methods for rinsing waters treatment and options for the water sludge utilization should be taken after the thorough feasibility study of the various options and their ecological and hygienic significance. Anyway, to introduce the already developed methods of utilization, it is necessary to accelerate the construction of shops for mechanical sludge dehydration at filter stations.

Besides, there is need for further research of the features of the formation and properties of a water-filled sludge formed in various water supply stations in various design features, in different fresh waters, improvement of well-known methods and development of new ones for economically and environmentally justified utilization to introduce them into practice. This will not only significantly improve the operation of water treatment facilities but will also contribute to the implementation of the objectives of environmental protection, improve the quality of life of the urban population and help in sustainable development of urban areas.

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